Combining Acoustic, In-Situ, and Remotely-Sensed Data with Regional Ocean Models in the East China and Philippine Seas

Bruce Cornuelle
Climate, Atmospheric Sciences, and Physical Oceanography Division
Scripps Institution of Oceanography
University of California San Diego
9500 Gilman Drive, 0230
La Jolla CA 92093-0230
Phone: (858) 534 4021 Fax: (858) 534 9820 email: bdc@uscsd.edu

Julie McClean
Climate, Atmospheric Sciences, and Physical Oceanography Division
Scripps Institution of Oceanography
University of California San Diego
9500 Gilman Drive, 0230
La Jolla CA 92093-0230
Phone: (858) 534 3030 Fax: (858) 534 9820 email: jmcclean@uscsd.edu

Award #: N00014-08-1-0587

LONG-TERM GOALS

The long-term scientific objective of the Quantifying, Predicting, and Exploiting (QPE) Uncertainty Directed Research Initiative (DRI) is to improve the assessment of uncertainty in observations and predictions of sound propagation in littoral regions. The objectives of this research are to understand and exploit the effects of the ocean state on acoustic propagation and detection.

OBJECTIVES

This work will contribute to the goals through global and regional physical ocean modeling and data assimilation. The modeling includes both model comparisons with observations, evaluating model error, and forecast and predictability studies to see the growth of uncertainty in time and space and the influences of the past ocean state on the acoustic propagation conditions on the shelf north of Taiwan.

APPROACH

The QPE DRI is a coordinated effort in which many types of measurements have been collected over the continental shelf to the north of Taiwan. The field results will be used to help characterize the rapidly varying physical environment in comparison to the models and to study acoustic propagation and scattering in the region. Two of the most important physical processes in the region of the experiment are the cold dome observed off the northwest corner of Taiwan and intrusions of the Kuroshio onto the shelf north of Taiwan.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2011		**00-00-2011 to 00-00-2011**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Combining Acoustic, In-Situ, and Remotely-Sensed Data with Regional Ocean Models in the East China and Philippine Seas	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of California San Diego,Scripps Institution of Oceanography,9500 Gilman Drive, 0230,La Jolla,CA,92093-0230**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Earlier observational studies (Yang et al., 1999; Zhang et al. 2001) reported intrusions of the Kuroshio Current into the East China Sea (ECS) to the north of Taiwan in the vicinity of the Mien-Hua Canyon (25.4°N, 122.5°E). Zhang et al (2001) analyzed observations from a moored current meter array (World Ocean Circulation Experiment PCM-1) that spanned the East Taiwan Channel between September 1994 and May 1996, and found a relationship between periods of low volume transport and those times when the Kuroshio intruded into the ECS. From surface drifter tracks they also observed a large Kuroshio meander to the south of the ETC that shifted the axis offshore and changed the flow field from its usual northward direction perpendicular to the PCM-1 array to nearly westward and parallel to the array line. Further, using altimetry data they related the low transport pulses to the arrival of anticyclonic eddies approaching the western boundary south of the PCM-1 array line. In an earlier observational study, however, Yang et al (1999) using drifters and altimetry related low transport pulses to the approach of cyclonic eddies and high transport events to the arrival of anticyclonic eddies.

Many previous studies have also focused on the cold dome, and a major hypothesis for its formation has been wind events. We used new modeling studies to evaluate these hypotheses and to understand the processes controlling both intrusions and cold dome.

WORK COMPLETED

In the past year, the project focus has been on detailed comparisons of the models with observations and examination of the phenomenology of the key oceanographic processes: the Cold Dome and Kuroshio intrusions onto the shelf northwest of Taiwan. We examined intrusions of the Kuroshio Current into the East China Sea in three high resolution model simulations: data assimilative 1/12° global Hybrid Coordinate Ocean Model (HYCOM; http://www.hycom.org), a forward simulation of 1/10° global Parallel Ocean Program (POP), and a regional forward simulation using the 1/24°MITgcm. All models were forced with synoptic atmospheric fluxes. Our goals were to:

1) Examine the conditions under which Kuroshio intrusions into the East China Sea occurred in the models.
2) Did these same conditions happen repeatedly?
3) Did they happen in all three models?
4) Were they in statistical agreement with observations?
5) What more could be learnt about the predictability of these processes from the high spatially and temporally resolved model fields?

We calculated volume transport anomalies through the East Taiwan Channel from all three models for the full duration of the periods that output was available at the highest archiving frequency available. This was daily in the cases of the MITgcm and HYCOM, and 10-daily from POP. Extreme volume transport events were defined as those values that exceeded two standard deviations of the demeaned daily volume transport time series. These extreme occurrences were averaged to form high and low composites of velocities at 15 m and sea surface height anomaly (SSHA). Simulated Lagrangian trajectories were released and tracked in the composite model velocity fields at 22° N off the east coast of Taiwan to understand the surface flow regimes during these extreme conditions.

Using HYCOM output as initial and boundary conditions, regional MITgcm model runs have been conducted in a domain which extends from 116°E to 128.5°E and from 22°N to 27°N. he To

compare model states at high and ultra-high horizontal resolution we used 1/24° and 1/48° grids. Both setups used 50 layers in the vertical, including 5m spacing near the surface.

The simulations were evaluated based on the realism of environmental features considered as keys for the observational program. The Kuroshio path was compared to float observations by Centurioni and Niiler as described above. The similarity of the "Cold Dome" feature in the model to historical observations and its mechanisms, sensitivity, and behavior was also examined.

The forward runs showed realistic Kuroshio position, including intrusions onto the shelf, and had generally good cold dome structure. Cold features were formed both by interaction of the Kuroshio with the topography and by strong wind forcing on the shelf. The cold features were also influenced by the Taiwan Strait flow and its seasonal variability. The cold dome timescale was seen to be approximately ten days. The upwelling of high-salinity Kuroshio water was seen in the center of the cyclonic eddy forming the cold dome in some cases. The region of the cold dome was defined by correlation analysis and a “cold dome index” was created by differencing the temperature inside the cold dome region with that outside.

RESULTS

The simulated trajectories from HYCOM, the MITgcm, and POP all showed that during the low event composite, the Kuroshio meandered offshore and then onshore to the east of Taiwan and then, intruded into the East China Sea in the vicinity of the Mien-Hua Canyon. Conversely, during the high event composite the Kuroshio followed the continental shelf as it flowed northwards with little intrusive activity. The low (high) composite SSHA fields (Fig. 1) showed the presence of cyclonic (anticyclonic) eddies to the east of Taiwan in agreement with the observational analyses of Yang et al. (1999). We refined earlier observational results by selecting real surface drifting buoy tracks (15 m) during low and high composite events using an equivalent SSHA extreme event criterion. The extreme drifter events during low and high composite events showed the same intrusive behavior during low volume transport (SSHA) events, in agreement with the model composite results.

These analyses were repeated for the model volume transport anomaly values occurring between 1 and 2 standard deviations of the demeaned time series. These composites did not show the same strong repeatability of intrusive or non-intrusive behavior, leading us to conclude that the strength of the mesoscale eddies are important to the predictability of the Kuroshio into the East China Sea. Currently we are examining the flow properties of the eddies approaching the Taiwan shelf during the two extreme states to relate mesoscale eddy strength to intrusive behavior over the continental shelf to the north of Taiwan.

The 1/24° resolution MITgcm runs have shown realistic Cold Dome statistics, based on comparisons to historical Taiwanese observations and SSH observations. The MITgcm improves on HYCOM in these respects. Further adjoint model runs have shown the strong nonlinearity of the region, limiting the time range of validity of the linearized gradients. This is in contrast to the linear predictability that comes from the coherent eddy features propagating from the east and in contrast to the linearity of the western boundary transport seen at lower latitudes. For both the cold dome and the shelf intrusions, control of the feature was seen to move upstream backward in time, suggesting that features of the Kuroshio itself governed the intrusions and the cold dome. In particular, the relation between intrusions and cyclonic eddies off the east coast of Taiwan were not obvious from the adjoint simulations.

The regional model was also used to simulate the ocean during the time of the intensive field program, including the effects of Typhoon Marokot, which caused significant damage to Taiwan and unleashed up to a meter of rain. Model runs using reanalysis forcing, but no runoff from Taiwan produced southward flow along the northeast coast of Taiwan 10 days after the passage of the cyclone, in qualitative agreement with observations. One hypothesis for the southward flow was the huge lens of fresh water near the coast from river run-off. The model result suggests an alternative mechanism for the same phenomenon.

A paper describing the Kuroshio intrusions as depicted by the three models and drifter data is being prepared for submission to the Journal of Marine Research QPE special issue. A second paper describing the cold dome simulations is in preparations for the same issue.

IMPACT/APPLICATIONS

This study will lead to the improvement of the assessment of uncertainty in observations and predictions of sound propagation in littoral regions.

TRANSITIONS

Methodology and data results can be made available to Navy scientists.

RELATED PROJECTS

The work described here is in collaboration with Dr Luca Centurioni at SIO and Dr Pierre Lermusiaux at MIT.

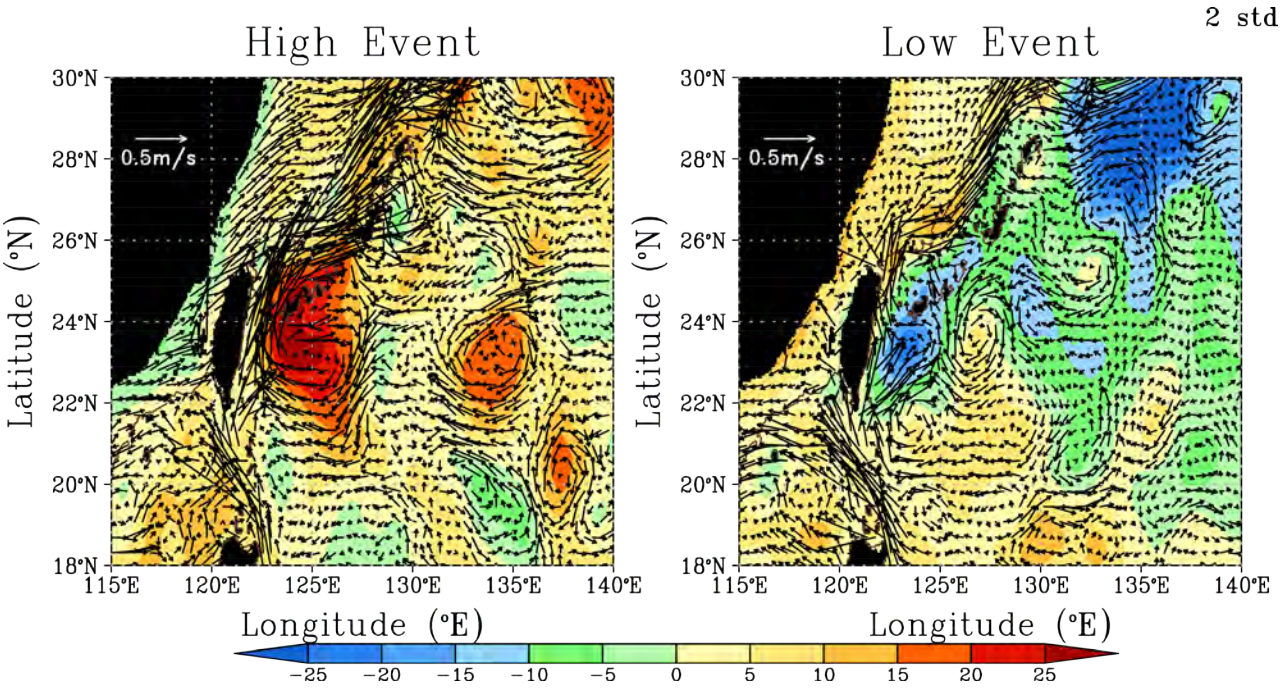

Fig. 1: High and low composites of HYCOM velocities (cm/sec) at 15 m and sea surface height anomaly (cm) constructed for occurrences of East Taiwan Channel volume transport anomalies that exceed the two standard deviation range of the demeaned time series.